Tampereen yliopisto

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POSSIBILITIES OF SOCIAL NETWORK ANALYSIS TO STUDY COMMUNICATION IN CONSTRUCTION PROJECTS

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ABSTRACT

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Construction project organizations consist of groups of specialists from different professional sectors. A successful completion of a complex and schedule pressed construction project requires effective communication between different stakeholders. The importance of communication for a successful construction project has been studied much, but the indicators determining good communication have been difficult to determine. One solution could be the use of social network analysis (SNA)

This bachelor's thesis investigates whether social network analysis makes it possible to analyze how various communication networks of a construction project are created, and whether social network analysis makes it possible to find out how well these communication networks function.

The study was conducted as a literature review, which aimed to find out what kind of research method the social network analysis is and weather it can be used to study networks in a construction project. The study found that researching communication and communication networks in a construction project is difficult. There are very few indicators that make it possible to make analyzes of the success of a communication. Studies show that communication is an important part of a successful project, which is why construction organizations need to focus resources on good information exchange and communication if they want to succeed in their projects. The social network analysis provides many tools and metrics that make it possible to study and analyze communication and information exchange processes. Based on this research, construction projects can be treated as networks that can be explored through social network analysis.

Social network analysis is suitable for examining the communication of a construction project with certain reservations. However, each construction project is unique, so a comparison between different projects is complicated. Nevertheless, the social network analysis is well suited for studying different communication networks and communication in one project.

Keywords: Social network analysis, graph theory, communication

TIIVISTELMÄ

Jesse Rauhamäki: Sosiaalisen verkostoanalyysin mahdollisuudet rakennushankkeen kommunikaation tutkimisessa
Kandidaatintyö
Tampereen yliopisto
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Rakennusprojektien organisaatiot koostuvat useiden eri alojen asiantuntijaryhmistä. Monimutkaisten ja nopeilla aikatauluilla toteutettavien rakennusprojektien onnistunut läpivienti vaatii näiden sidosryhmien välillä toimivaa kommunikaatiota. Kommunikaation merkitystä onnistuneelle rakennusprojektille on tutkittu paljon, mutta onnistuneen kommunikaation määrittämiseen olevia mittareita on ollut vaikea määrittää. Yhtenä mahdollisuutena on esitetty sosiaalisen verkostoanalyysin (SVA) käyttöä.

Tässä kandidaatintyössä tutkitaan, onko sosiaalisen verkostoanalyysin avulla mahdollista selvittää, miten rakennusprojektin erilaiset kommunikaatioverkostot syntyvät, ja miten hyvin kyseiset kommunikaatioverkostot toimivat.

Tutkimus tehtiin kirjallisuusselvityksenä, jossa pyrittiin selvittämään, millainen sosiaalinen verkostoanalyysi on tutkimusmuotona ja voidaanko sitä hyödyntää rakennusprojektin kommunikaatioverkostojen tutkimisessa. Tutkimuksessa havaittiin, että kommunikaation ja kommunikaatioverkostojen tutkiminen rakennusprojektissa on hankalaa. Mittareita, joiden avulla on mahdollista tehdä analyysejä kommunikaation onnistumisesta, on olemassa hyvin vähän. Tutkimukset osoittavat kommunikaation olevan tärkeä osa-alue onnistuneelle projektille, minkä vuoksi rakennusorganisaatioiden tulee keskittää resursseja hyvään informaatiovaihtoon ja kommunikaatioon, mikäli ne haluavat onnistua projekteissaan. Sosiaalinen verkostoanalyysi tarjoaa paljon työkaluja ja mittareita, joiden avulla kommunikaatiota ja informaationvaihtoprosesseja on mahdollista tutkia ja analysoida. Tämän tutkimuksen perusteella rakennusprojekteja voidaan käsitellä verkostoina, joita on mahdollista tutkia sosiaalisen verkostoanalyysin avulla.

Sosiaalinen verkostoanalyysi sopii rakennushankkeen kommunikaation tutkimiseen tietyin varauksin. Jokainen rakennushanke on uniikki, joten vertailu eri projektien välillä on hankalaa. Sosiaalinen verkostoanalyysi kuitenkin sopii hyvin yhden projektin eri kommunikaatioverkostojen ja kommunikaation tutkimiseen.

Avainsanat: Sosiaalinen verkostoanalyysi, verkkoteoria, kommunikaatio

CONTENTS

1. INTRODUCTION

1.1 Background

Construction industry has become more fragmented and projects consists of multiple stakeholders with their own expertise. Together all these actors must meet the challenges required by complex construction projects. Tools to study cooperation between these stakeholders are not that many, even though communication is flagged as one of the key factors for a successful project. Communication and information exchange should happen on time and it should be complete and accurate. Communication happens between all the stakeholders and inside their own organizations. This study examines the possibility of social network analysis to be used when studying communication networks between different stakeholders in a construction project.

1.2 Research problem and research questions

The research questions are:

- what type of research method social network analysis is and what type of projects can be studied with social network analysis
- what possibilities social network analysis offers when studying construction projects.

The aim is to study how does social network analysis fit to study communication in construction projects and does social network analysis offer a new way to approach studying communication between various stakeholders.

1.3 Scope of the research

Thesis is narrowed to study how social network analysis works when studying the different communication networks between different stakeholders in construction projects. Different formulas used in social network analysis are not opened in this thesis.

1.4 Objectives of the research

Objective of this research is to find the possibilities that social network analysis offers when used in construction projects. The intention is to estimate if social network analysis can be adapted to study communication in construction projects and what are the characteristics of social network analysis.

1.5 Research methods and structure of the thesis

In this bachelor's thesis the research method used is literary review to study social networks history, properties, restrictions, typical uses and how social network analysis has been applied to study construction projects. Thesis consists of four chapters. Chapter 2 focuses on social network analysis, its characteristics, most used meters and its history. Chapter 3 consists of studying construction project as a network of relationships and how communication affects the outcome of a project. Chapter 4 is the summary chapter, where the work is evaluated, and further research proposals are introduced.

2. SOCIAL NETWORK ANALYSIS

In this chapter social network analysis is described. In chapter 2.1 the history of social network analysis (SNA) is reviewed and explained how it is connected to the graph theory and how it can be applied to study communication. The most common terms used in graph theory are presented in Chapter 2.2. In Chapter 2.3 is introduced how actors and groups are defined in SNA and given different options to present networks. Chapter 2.4 and 2.5 focus on different meters and indicators used in SNA. Social network analysis (SNA) has gotten more attention in construction industry since it has been noticed that trust and communication between different stakeholders needs more awareness (Morton et al. 2006; Katsanis 2006). Haythornthwaite (1996, p. 335-356) states that information is a vital resource that often necessitates contacting the right person. Social network analysis offers on a wide scale of different techniques how to portray and explain how individuals can connect into that information. Using SNA also can explain how different groups and individuals affect the information exchange process.

2.1 History of social network analysis

Social network analysis is a limited set of links between a set of predetermined actors. From these connected links, it is possible to determine how a person acts in this social network. (Mitchell 1969, p. 2; Wasserman & Faust 1994, p. 20). Social network analysis is based on the graph theory and presents the organizations, groups or individuals that work in the network as nodes or actors and their connections as links (Scott 1991, p. 7). Moreno (1960) was the first to introduce the use of social network analysis to study interactions between groups. In these first models, graphs or sociograms were used to portrait individual relationships that created larger social networks. Matrixes were used to express individual's relationships in a group or a community. From these matrixes, it was possible to draw graphs where nodes represented actors and the lines represented relationships between them, for example an information exchange. Individuals are dependent from each other and are parts in complex and dynamic social networks. These networks influence on their behavior and the relationships between actors are just as important as individuals in the networks. Change is constant in a social network (Wasserman & Faust 1994, p. 3).

2.2 Terms used in graph theory

Most indicators in SNA are based on graph theory, which consists of mathematical formulas and concepts. (Alba 1982; Scott 1991; Wasserman & Faust 1994). Social network analysis has taken multiple concepts from graph theory to its own use. Freeman (1978, p. 218) has defined the basis of graph theory as follows:

- When two nodes are connected straight to each other, the have an **adjacency**.
- That connection can have a direction and that type of connection is called an **arc**. A connection without a direction is called an **edge**. In networks that have directions, this direction is usually visualized using an **arrow**.
- Networks that have connections with a direction are called **digraphs**.
- The number of direct contacts a node has to other nodes is called a **degree**. In directed networks or digraphs, this is calculated as in-degree for incoming connections and as an out-degree for outgoing connections.
- A specific route from one node to another node is called a **path.** The length of the path tells how many nodes the route goes through. If two nodes can be connected directly or via other nodes, there is reachability between those two nodes.
- Distance between two nodes is the shortest path between them. In digraphs when calculating the path and distance, the direction of the connections must be taken into account.
- When all the nodes can be reached from every other node, the network is called a **complete graph**.
- Arcs and edges can also have values to show the intensity or the strength of the connection. These types of networks are called **valued graphs**.

2.3 Actors and relationships

Different actors in the networks can be individuals, companies, organizations or any other type of a social group (Wasserman & Faust 1994). Haythornthwaite (1996, p. 325, 330) states that actors' different positions and roles in the network can be identified empirically using social network analysis. SNA recognizes similarity between actors by their behavior, not by the titles of the actors. First, the actors are defined by their relationships and only after that the actors are divided into groups.

Burt (1995) says that actors' exposure to information in a group can be limited by the useless information by actor's contacts. If individual's contacts have access only to the same information that the individual has, they cannot provide any new information for this actor. If an actor has connections to other networks, this individual can bring this information to the group and so improve possibilities for everyone in the group. The way actors or actors' groups can control or ease the flow of information, be central or at the edges of the network, be strongly or weakly connected illustrates the social structure of the environment (Haythornthwaite 1996, p. 325, 337).

Relationships represent a connection between two or more actors. Those can include the distribution, delivery and distribution of different resources like information. Relationships can be defined by their contents. A pair that holds up a certain relationship is linked by that relationship; for example, people who work together are linked by their employment relationship. Pairs can have more than one relationship with each other. Pairs are tied by all their relationships. (Haythornthwaite 1996, p. 326)

Relationships also include contracts and economic relations between organizations (Wasserman & Faust 1994, p. 20). Loosemore (1996; 1998; 1999) argues that social network analysis in construction branch context should especially be looked through the company's point of view. When studying construction projects objectives, contracts between different companies are in a vital role and that is why they should be in the focus instead of relationships between individual workers.

Nohria and Eccles (1992) say that there are five main principles when studying actors' network, which are as follows:

1. Cohesion, grouping of actors by their common strong relationships.
2. Structural equivalence, grouping of actors by the similarity of their relationships.
3. Status, that shows which actor is in command.
4. Reach, that shows extent of actor's network
5. Centrality, which shows bridges to other networks.

Haythornthwaite (1996, p. 327) continues that strength of the relationship means the intensity of the connection. In a relationship where actors meet often and a lot of information is changed, the relation is stronger than in a relationship where actors meet rarely, and information exchange is limited. Relationships can be reviewed also without the strength, if only the mere connection between actors is considered as a sufficient factor for the importance of the relationship. Relationships can also be ignored if it is decided that there must be a minimum amount of communication between the actors so that the relationship is considered important. Strength of the link shows the strength of the linkage between actors, that may depend on how many and which type of relationships the pair upholds and the strength of these relationships. The strength of the link is important when determining how the actor is connected to its surroundings and the possibility of information transferred/delivered from one actor to other although finding the right meter for link strength can be hard. Usually the existence of strong links has been considered increasing information exchange (Festinger et al. 1950). Individuals who are closely connected to other people own more intimate relationships and are more willing

to share information with others. Granovetter (1973, p. 1371) on the other hand argues that individuals who have more weak links are more prone to move in different groups and obtain different types of information than those who have strong links but only move inside the same group. He continues that weak links are important in delivering/transferring new and innovative information. Haythornthwaite (1996, p. 336) states that strong and close relationships between actors inside a network encourages to a free information exchange but if they are too close, they might instead hinder it. The actor may not create and uphold new relationships which weakens his/her access to new information. Existing networks might define to whom an actor can be in contact with and so hinder actors' possibilities. These restrictions are a disadvantage to an actor in actors' operating environment.

Structural equivalence recognizes actors who have similar type of roles. Actors can be defined equivalent if they fill in the same role in relation to other actors in the same networks. In other words, they have identical relationships as a sender and a receiver inside the network. (Wasserman & Faust 1994, s. 356; Haythornthwaite 1996, p. 334)

Reach means the selection of sources that are available for the actor. The more links actor has and upholds, the more social resources actor has in use and more locations to use these resources. (Burt 1995). Actors' range depends on of the size of the actors' own networks, amount of those relationships that act as bridges to new networks and the extent of those networks that the actor is connected to. Reach can be studied by measuring to how many actors the actor is connected directly or connected indirectly. The more networks the actor is connected to, the more actor has information possibilities, and, in addition the more varied information is available to the actor. (Haythornthwaite 1996, p. 335)

Haythornthwaite (1996, p. 336) explains that centrality means connections between different groups. These connections are opportunities for the actors in these central positions. An intermediary can communicate information from one group to another and so control the information flow. This is measured by betweenness-centrality that shows at what level the actor is between other actors inside a network. Actors can act as important intermediaries even if they only have a few connections inside the network.

Betweenness-centrality measures how much actor acts as a gatekeeper and how much he has possibilities to control others (Scott 1991, p. 89-90). Haythornthwaite (1996, p. 336) continues that an actor who acts up as a gatekeeper is filling an important role of filtering and delivering information inside the network. A network that has a possibility for an intermediary, but that role is not filled, has a structural hole. An actor can strive for

this position to drive actors' own or actors' groups benefits. Centrality is further reviewed in subchapter 2.4.1.

Wasserman and Faust (1994, p. 18) have presented the most important relationships. In addition, Pryke (2004, p. 793) has defined the most important relationships in a construction project, which are specified with cursive in following:

1. One's evaluation of another person that appears for example as a friendship.
2. *Exchange of materials, for example business transactions, loaning or renting of materials*.
3. Collaboration or a connection, for example attending the same social event or belonging to the same social group.
4. *Behavioral interaction, for example talking with each other or sending messages*.
5. Moving between places or stations, for example social or physical moving.
6. A physical connection, for example a road or a bridge that connects two points.
7. *Official relations, for example authority*.
8. Biological relations, for example kinship.

Social networks can be studied either as whole networks which are sociocentric or as personal networks which are egocentric. An egocentric network presents how one actor acts in a network. Sociocentric networks presents how the whole network works in its operating environment. All the relationships that a single actor maintains with other actors form an actor's local network. Using personal networks, it is possible to study one actor's relationships to other actors in a certain environment and examine what type of relationships actor maintains, what information actors provides and what information actor receives from other actors in the network.

Whole networks represent all the ties between all the members in a certain environment. A personal network can reveal who a person asks for information and who offers it. This data can be used to form a model for information seeking behaviors that can help new individuals to find more efficient ways to seek information. It can also be used to modify information services so that they support user's behavior and users can be guided to right information sources. By studying the whole network, information providers can recognize groups that need similar types of information, for example. Actors inside an organization might need the same information even if their positions might be different or they might even work in completely different organizations. It is also possible to identify the keypersons that provide much information or recognize spots where getting information is not possible, so that information providers can fill these spots and help the whole organization. (Haythornthwaite 1996, p. 328-329)

When information is moved from one person to another, it moves in a certain direction. Instructions that tell what to do flow from chief to the worker. This type of relationship is asymmetric, because information flows only in one direction. This type of relationships can be also found between equal co-workers. Relationships can also be undirected. In these networks direction of the relationship is not measured, or it is not considered to be relevant. Relationships describe a certain type relation between individuals, groups or organizations. They can be directed connections that contain information or other resources. They can also be undirected where both actors exchange similar type of resource, but the amount of that resource might vary. Diverse relationships between actors form up the ties between actors. The more relationships an actor maintains, the more reciprocal they are and the more personal they are. Also, the longer the relationships have lasted, the stronger the ties are. The stronger the ties are between actors, the more willing the actor is to share information. (Haythornthwaite 1996, p. 327-328)

In directed networks, every line has a direction so every line must be reviewed by its direction of travel. The number of relationships gets two different definitions, a number of senders and a number of receivers. Total amount of senders is the sum of those lines that are directed away from the node and the total amount of receivers is the sum of those lines that are directed to the node. The number of receivers are shown in the columns of the matrix and the number of senders in the rows of the matrix. A path in a directed network must follow the direction of lines. When studying information exchange between actors, it is recommended to use a directed network, then it is possible to recognize those actors who act either as information sinks or sources. (Scott 1991, p. 72)

2.3.1 Factions

A faction is a group of individuals that communicate with each other more than with other people (Glover 1989). Monge (1987, p. 242) states that factions are formed when they are tightly connected inside a network. Inside networks there is a possibility to recognize different factions. The simplest faction is a component, that means that all the actors are connected to each other via paths and there are no paths out of the group. In directed networks, all the paths between actors must be in the same direction. This is called a strong component. This is used to delimit the studied network. (Scott 1991, p. 104; Johanson et al. 1995, p. 63)

A cycle is a path that always returns to its starting point. When studying cycles, they are defined by their length; for example, a cycle of three. In order that the configuration satisfies the definition of a cycle, each path can be only used once. Cycles can also be

studied in directed and non-directed networks. A cycle is strong when in a directed network the direction of the path remains the same in the whole cycle. (Scott 1991, p. 108-109; Johanson et al. 1995, p. 64)

One of the most used faction is called a clique. A component formed by two cliques is presented in Figure 1.

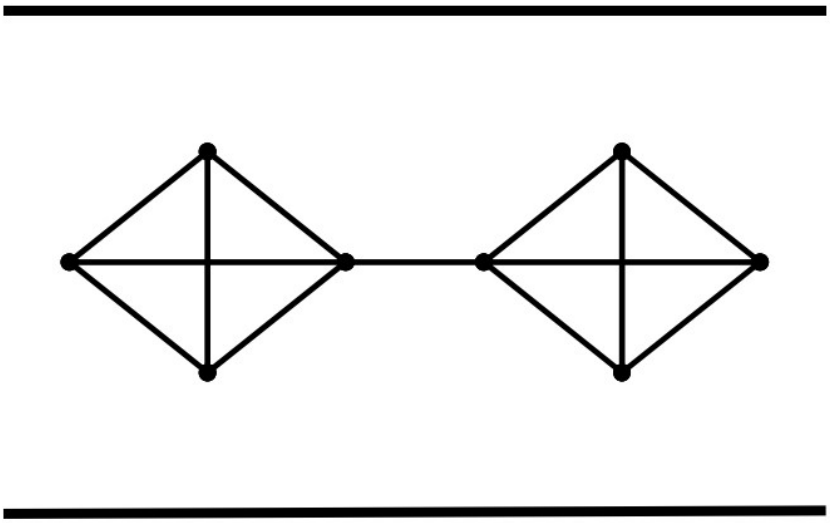

Figure 1. *Sociogram formed from two cliques. Modified from source: (Haythornthwaite 1996, p. 332)*

In a clique, all actors are connected to each other and it is not a part of another clique. Unlike in a component, all actors are connected directly and not via intermediaries. Typically, minimum size for a clique is three actors. Actors can be simultaneously a part of multiple cliques. Several programs made to study networks offer a possibility to check which cliques actor belongs to and how much cliques overlap. In very scattered networks n-cliques can be used. Then paths with length of n are allowed in a clique. (Scott 1991; Johanson et al. 1995, p. 65-67)

2.3.1 Presentation of networks

In social network analysis traditionally three formal notation schemes are used to describe networks. These are sociometric notation, graph theoretic notation and algebraic notation. Sociometric notation uses matrixes that have the same units on both columns and rows, a case by case matrix. The values of a matrix indicate a relationship between rows and columns. In a one-dimensional matrix, the rows and columns describe the same actors, and it is called NxN matrix. In addition to the existence of a relationship, a

value can also include, for example, the intensity of the relationship. (Scott 1991, p. 39-42; Johanson et al. 1995, p. 37-40)

A matrix can be represented as a graph according to graph theory that allows the analyzing of shapes. A matrix is a numeral representation of the graphs data. In the graph, nodes represent actors and lines between them relationships. (Scott 1991,p. 66; Wasserman & Faust 1994; Haythornthwaite 1996, p. 324; Loosemore 1998, p. 316). Shape of the graph is important, but the relative placement of the points and length of the lines presented are irrelevant (Scott 1991, p. 67).

In the study of group dynamics, sociograms were adapted together with the idea that individuals or organizations change information in each event (Scott 1991; Haythornthwaite 1996; Chinowsky et al. 2008). Assuming that every event needs the flow of information, these events can be mapped with sociograms (Wasserman & Faust 1994). Alba (1982) on the other hand states that the mathematical study of the data contained in graphs is the true strength of network analysis in communication analysis, allowing to study group efficiency and weaknesses. In addition to these, networks can be presented in algebraic notation which is outside of the scope of this thesis.

Haythornthwaite (1996, p. 325) explains that a sociogram tries to represent all the columns and rows of the corresponding matrix. Forms in the graph reveal how an individual seeks and sends information and how the individual is exposed to information, new ideas and opportunities. This technique of visualization allows for an excellent opportunity to recognize structural flaws in the project network. Figure 2 shows an example of a centralized network where the project manager has a central position. Figure 3 shows an example network where architects are isolated from the communication network.

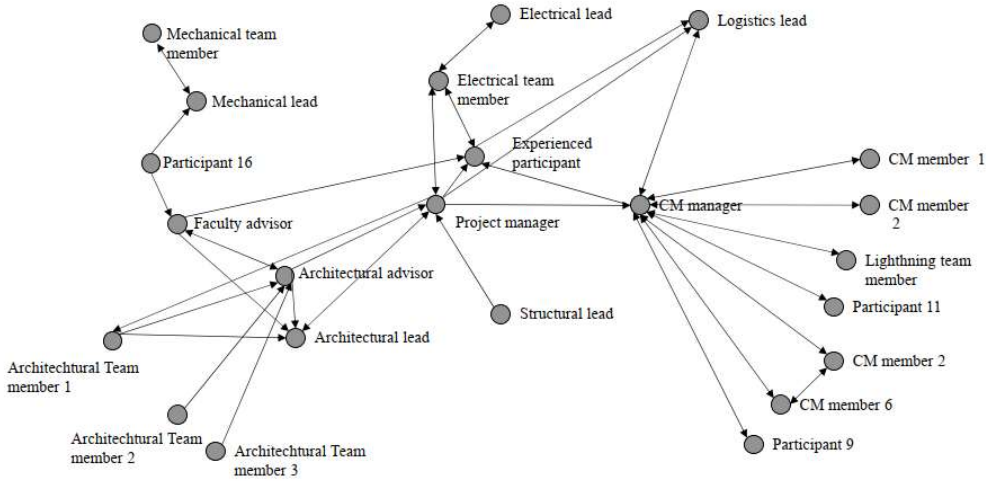

Figure 2. *Example network of a centralized network. Modified from source: (Chinowsky et al. 2008, s. 809)*

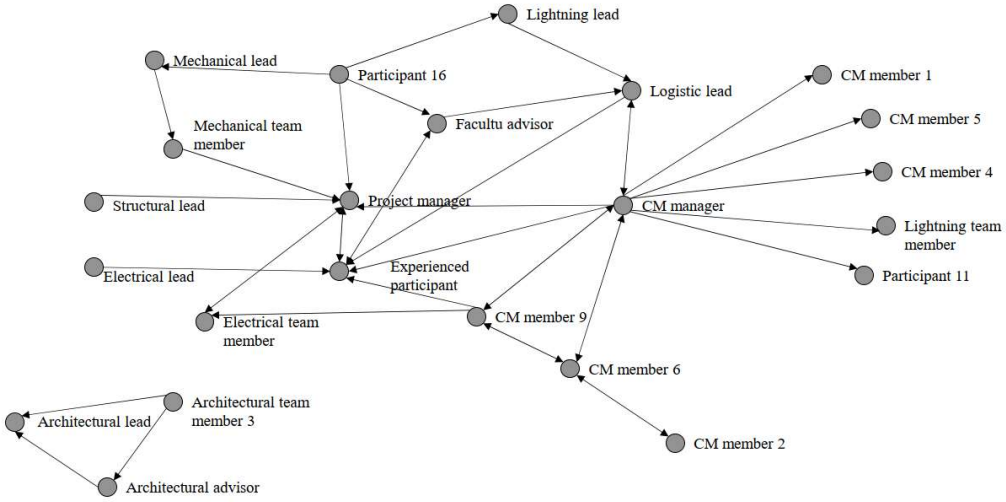

Figure 3. *Example of a decision-making network where one stakeholder group is isolated. Modified from source: (Chinowsky et al. 2008, p. 810)*

Concentration on the type of relationships, such as who changes information with who and who works with who distinguishes social network analysis form other analysis techniques (Haythornthwaite 1996, p. 324, 326).

2.4 Centrality and centralization

By studying the positions of actors, it can be estimated which actors have the influence or power in decision making in the network (Nohria & Eccles 1992, p. 6). This can be measured by assessing individual's centrality in the network, which should not be con-

fused with centralization discussed later in Chapter 2.4.2. Centrality measures one actors' connections in the networks and not the connections of the whole network. Centrality was first introduced by Bavelas (1950) and later specified by Leavitt (1951). Freeman (1978, p. 236) has defined three indicators of centrality: 1) degree-centrality, 2) closeness-centrality and 3) betweenness-centrality. There are also other types of centrality such as the Bonacich-degree which are outside of the scope of this thesis. Also, formulas for calculating different centrality and centralizations are outside of the scope of this thesis.

2.4.1 Centrality

Degree-centrality describes how an actor is connected to other actors. This shows actors' activity in the networks, i.e. the extent of which the actor is connected to its nearest neighbors. A high degree means plenty of interaction with other actors in the network. In a directed network the outdegree-centrality and the indegree-centrality can be distinguished. Outdegree expresses how much the actor sends information, and indegree how much actor receives information. (Freeman 1978, p. 236; Scott 1991, p. 85; Johanson et al. 1995, p. 51)

If an actor has a high indegree, the actor can act as a sink. They are popular actors in the network and have a lot of information possibilities. On the other hand, if an actor has a high outdegree, they are considered as sources and they can affect the information that flows to the network and the networks is dependent of that actor. (Freeman 1978; Scott 1991; Johanson et al. 1995)

In Figure 4, a simplified network 1 where the actor A is the most central, and it has 5 connections is presented. This position gives the actor plenty of possibilities to access information from other actors in the network and also a good position to deliver information to others, or to hinder information from flowing. The other extreme is an isolate where the actor does not have any connections. This type of an actor can only get information from impersonal sources and has no way of sharing this in the network. Isolated actors might be unused information resources. (Haythornthwaite 1996, p. 334-335)

Betweenness- centrality and closeness-centrality are used when examining actors' relationships to the whole network (Johanson et al. 1995, p. 53). Closeness-centrality describes how close the node is from other actors in the network. Closeness-centrality is smallest with the central actors in the network. Closeness-centrality is the sum of actor's shortest paths to every other actor in the network. Closeness- centrality expresses how the whole network is close to only to one or a few actors. A path shows how many inter-

mediates are needed that two actors can communicate (Freeman 1978; Scott 1991; Johanson et al. 1995). Freeman (1978) has said that the closeness of nodes tells about actors independency, if an actor is close to many other actors, he/she might have problems working independently without other actors interfering. In turn they have possibilities to monitor and control more and spread ideas and decisions quickly to a wider audience.

Betweenness-centrality indicates how an actor is located between different actors in the network. It is measured by calculating the amount of the shortest paths between two actors where the actor is involved. This tells how much the actor acts as a gatekeeper or a coordinator between individuals or groups. (Freeman 1978; Scott 1991; Johanson et al. 1995). According to the Tushman and Katz (1980, p. 1071) the gatekeepers do not only transmit the information from outside the group but they also ease the communication outwards from the group. A gatekeeper is a keyperson that has strong connections both in their own organization and to the outside organizations.

Freeman (1978) has stated that individuals who have high betweenness-centrality can influence other actors by controlling and filtering information that flows through them. These individuals are powerful actors inside the network and are in a critical position to uphold free and open information flow though the network. Cohn and Marriott (1958) demonstrated that these individuals keep the whole information system together and weaknesses in these critical points can lead to the fragmentation of the whole network. Betweenness-centrality is a good indicator of networks vulnerability because it indicates in what extent the information flow is limited by a few actors. A network is vulnerable because these individuals can manipulate information to their own gain. (Freeman 1978; Haythornthwaite 1996)

Haythornthwaite (1996, p. 335) states that all the meters of centrality express the possibilities of sending and receiving information. By controlling, filtering or enabling the information flow, the key actors can create, maintain or block information routes. They are the best places for information enablers that can encourage new routes to be created. However, these places or rather actors must be recognized first in the network. Cross et al. (2002, p. 27) continue that by recognizing these individuals, organizations' management can arrange information and decision-making rights and responsibilities in that way that the whole group acts more efficiently. Also identifying the actors who are on the outskirts of the network and finding ways to include them in information flow, is a way to ensure that nobody's expertise is in vain.

Measuring the centrality of a network allows an analysis to be made of the groups' internal relationships in a network that is organized by project organizations functions. Comparing the degrees of a given actor in different networks, such as a communication network or a design management network, it is possible to make quantitative comparison between different project management methods when roles and relationships between actors are changed. (Pryke 2004)

2.4.2 Centralization

Centralization describes the whole network and measures in which degree the actors are centered around one central point. Figure 4 shows a highly centralized network (network 1) where all the groups are connected to each other via one central actor. In this network information that goes from actor B to actor C must go through intermediary A. This type of network is called a star network, which is the most centralized network. If a network is organized as least centralized form, which is called a circle-network, the information process contains much more intermediaries which increases the potential for errors in information exchange. The third network is called a chain, which is an intermediate form of the two previous. The way the actors are located inside the network affects much how quickly and easily information can be shared with all the actors. Recognizing these forms is important so that the form can be actively adjusted to improve information exchange. (Haythornthwaite 1996, p 333-334)

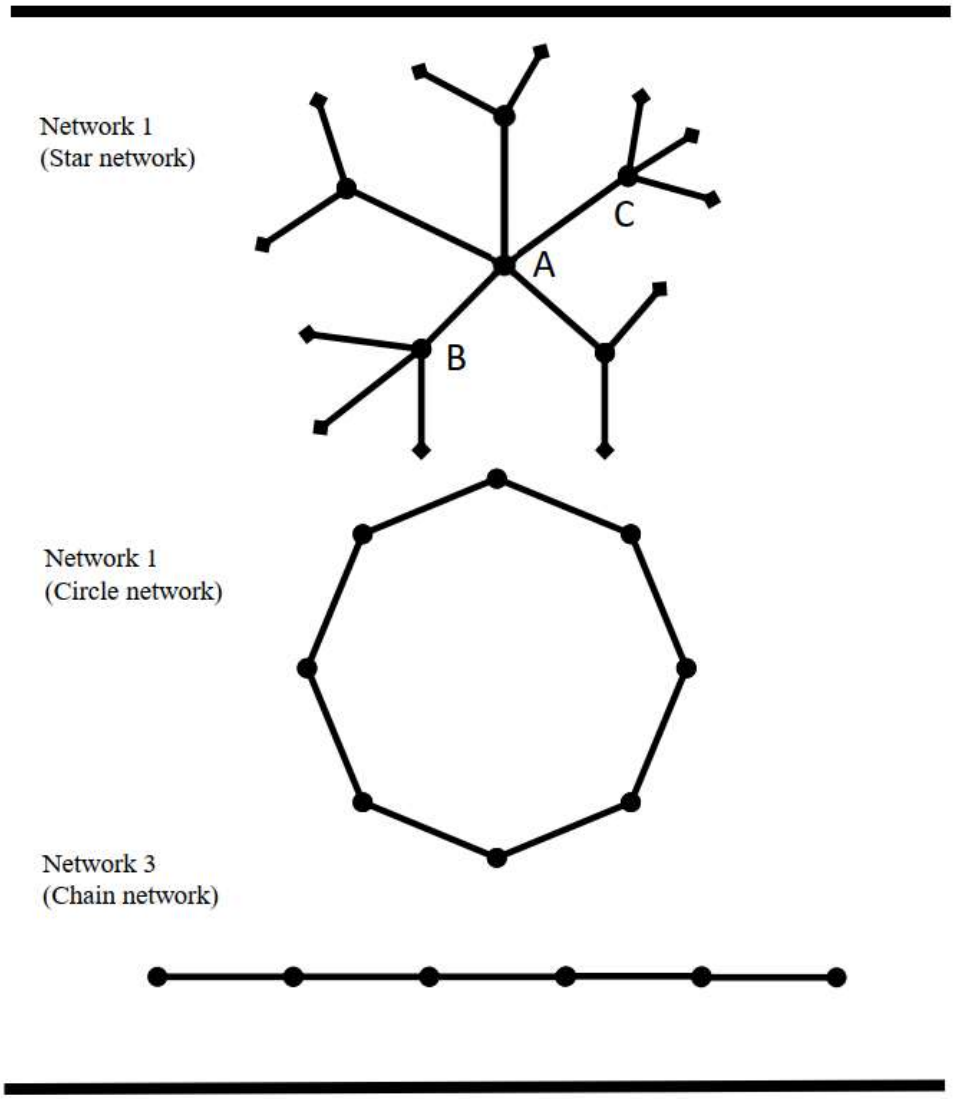

Figure 4. *Three types of centralized graphs. Modified from source: (Johanson et al. 1995, p. 57; Haythornthwaite 1996, p. 333)*

2.5 Density

Haythornthwaite (1996, p. 332) explains that just like the centralization of the network also the density of the network describes the properties of the whole network. It can be used to demonstrate the existence of strong relationships and the probability for them. They allow actors access to the same recourses and information and show the level at which the actors communicate with all the other actors. By identifying those parts that have higher density, it is possible to recognize network structures like factions and cliques. Network density is one of the most widely used concepts of graph theory that allows analyzing of social networks and it is an indicator of how close a group is (Johanson et al. 1995, p. 44). Haythornthwaite (1996, p. 332) continues that density describes

how networks actors are linked to all other actors. It is the ratio of all connections to all possible relationships in the entire population. On general level, density indicates how loose or tight the social structure in the network is. The concept of network density is aiming to study how much the considered network differs from a complete network. A complete network is a network where every node is connected to every other node, but these types of networks are rare in real life situations. The larger part of the network that is connected the denser network is considered. (Scott 1991, p. 73)

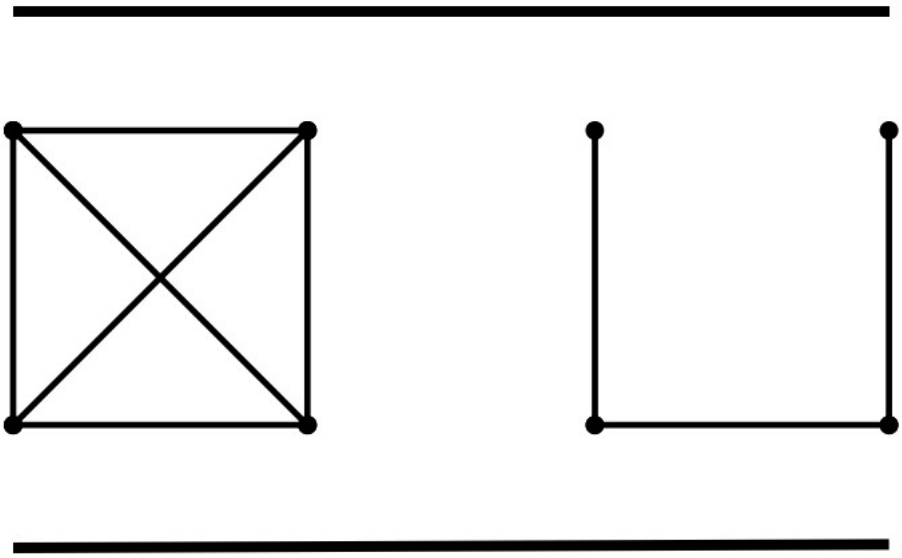

Figure 5. *High-density network on left and low-density network on right. Modified from source: (Haythornthwaite 1996, p. 333)*

In Figure 5, a simple network with low and high densities are presented. Even though in both networks all the nodes are connected can information flow in a low-density network only go through one route while in the high-density network it can flow from everywhere to anywhere. Information flows are considered freer in high density networks. (Haythornthwaite 1996, p. 332-333). Density is defined by using networks inclusiveness and number of its node's connections. Inclusiveness means the number of all the nodes reduced by the number of nodes that are not connected to the network. (Scott 1991, p. 73-74) Formulas for calculating density are outside of the scope of this thesis.

3. CURRENT STATE ANALYSIS OF COMMUNICATION IN CONSTRUCTION PROJECTS

Information flow in construction projects is a vital part of its success. Chapter 3 focuses on how construction networks are created and how communication affects projects. In Chapter 3.1 is discussed how construction and project organizations can be considered as networks. How communication affects the outcome of a construction project is studied in Chapter 3.2. In Chapter 3.3 is discussed how SNA can be used in construction projects.

3.1 Construction project as a network of relationships

A construction project is typically a temporary organization, and a construction company is a permanent organization, that tries to develop the built environment (Winch 1989, p. 331). Pryke (2012, p. 64) on the other hand says that a construction project can be defined as diverse and information dependent prototype where the construction phase and the design phase are happening simultaneously and are strongly dependent of each other, including plenty of inner and outer uncertainty factors. Companies are attached to each other by flows of information and materials in temporary project organizations (Winch 1989, p. 339). Winch (2012) later continues that temporary project organization can be considered as a network of information flows. Fellows et al. (2002) describes a construction project as a matrix of relationships where each project consists of multiple information exchanges between different companies. Organizations are open systems that are in constant interaction with their environment and must be able to adapt to the changes happening in their environment (Ruuska 2007). Winch (1989; 2000) has defined a project organization as follows:

- A project organization is gathered for only one project and it does not have a framework for collaboration.
- A project organization consists of multiple companies that work together and are dependent of each other to achieve success.
- A company's or individual's possibilities to influence on the project outcome are not tied to their position in the hierarchy chart.
- The modes of information exchange and financial relationships between interest groups are more important than their official contractual relationships when organizations actions are considered.

The concept that construction projects are unstable networks that transform for every project has affected on the idea of a successful project network. This link between traditional graph theory and the desire to develop the project is the motivation to link graph theory to successful projects and teams, where every construction project is a combination of social interaction and project collaboration. (Chinowsky et al. 2008, p. 806)

Winch (1989, p. 334, 338) states that uncertainties in construction projects are one of the main problems for the construction management. The project nature of construction activities might create tensions inside the project consortium between the different companies involved that leads to uncertainty in the whole project. In a construction project the uncertainty is reducing as time passes and the amount of information increases, as is presented in Figure 6 (Winch 2001, p. 800).

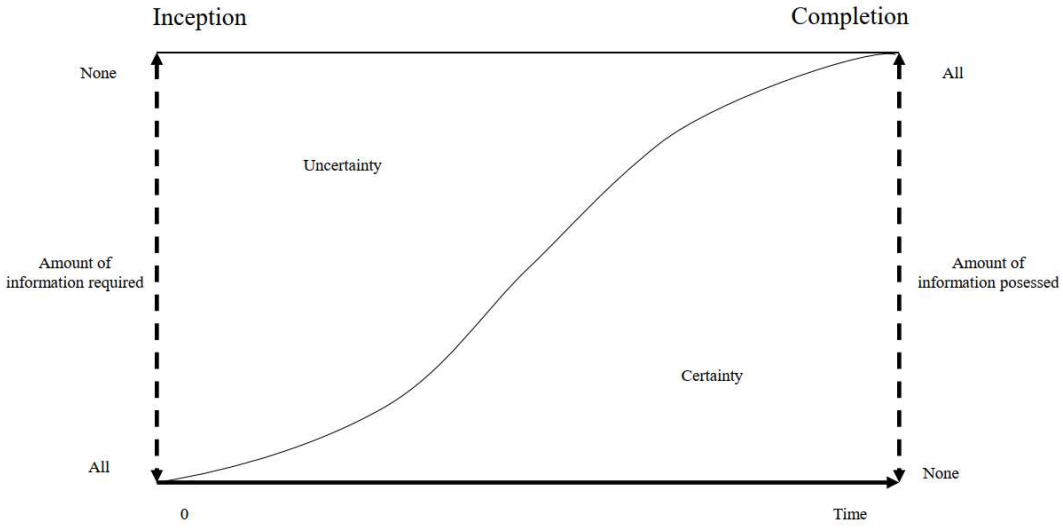

Figure 6. *Reduction of project uncertainty as the project progresses. Modified from source: (Winch 2001, p. 801).*

Traditionally the planning of a construction project has centered around the idea that most of the problems can and should be recognized and solved before the actual construction phase. So, the efficiency of the project has been assumed to be improved by identifying what information must be changed between the actors in the project organization during the construction phase before the construction phase has started. This makes the project organization to act reactively, with emphasis in finding and asking for information to solve one specific task, so the information is sought only to achieve this one topical goal. However, high performance teams do not act reactively, whereas they focus on the possibility of constant and free information exchange between the members. (Chinowsky et al. 2008, p. 804)

Chan ja Kumaraswamy (1997, p. 62) emphasize information exchange between all project stakeholders and the need for effective data processing systems. Fast communication and decision-making between all stakeholders require right organizational structures and communication systems, bringing all project stakeholders together. These systems must be developed throughout the life cycle of a project and the roles and responsibilities of project personal must be clearly defined and declared.

3.2 Importance of communication in a construction project

According to Luiten and Tolman (1997, p. 113) one response to the increased demands for better quality, more complex solutions, shorter and tighter schedules, lower costs, less stress for environment and for better working conditions etc. is the more effective use of the information and knowledge already available. The necessary data is obtained from earlier experiences, feedback from earlier projects, recent research results, new material and technology development, and so on. Already used computer programs produce plenty of information about projects, companies etc. However, the exchange of information between the project actors has not been developed at the same speed that the technology has improved which has led to increase in the differentiation of information.

Luiten and Tolman (1997, p. 113) defined the communication in a construction project as the exchange of knowledge and information. The successful communication links the elements of the project together inside the project and links the project to its operating environment. (Ruuska 2007, p. 83)

The first law of Wiio (1978) says that communication fails always, except by change. So, it is no wonder that lack of effective communication is a constant problem in achieving a successful project (Thomas et al. 1998, p. 65).

Ruuska (2007, p. 23) says that every project is community that is in constant cooperation from the beginning of the project to the end of the project. To work efficiently the project must have a properly working communication system, because projects are led through communication. Communication should be handled as a resource that needs planning, management and control. Successful communication ensures the right and effective use of all other resources. Information flows should be managed like any other construction projects process, like materials, and they should be steered in the right direction inside the project organization (Winch 2001, p. 799).

According to list composed by Thaim and Wilemon (1986) the *effective communication in project groups i*s the third most important factor that affect success of the project.

Thamain (1992) continued by listing the thirty biggest problems that have a negative effect on the project outcome, and they can be organized in five different categories as follows:

1. Problems in organizing the project team
2. Weak leadership in the project
3. Communication problems
4. Conflicts and misunderstandings
5. Insufficient involvement by upper management

All five categories include communication in some level, even though communication is listed as its own category. For example, organizing a team needs clear communication skills. Conflicts and misunderstandings are usually the consequence of bad or inefficient communication. Chinowsky et al. (2008, p. 806) state that one of the most important part of communication in a construction project is communication inside small groups. Construction teams must have effective interaction and should produce needed solutions quickly.

Every group experiences the same steps when finding solutions to their problems (Fisher 1974). Groups which understand the process and the factors affecting to its different steps have a greater chance to successfully finish the task (Poole & Roth 1989). Thomas et al. (1998, p. 58) argue that meaningful information must be recognized and shared between teams' actors during the entire lifecycle of the project. The performance can be improved by using efficient project communication and vice versa, projects can fail if they are hindered by bad communication. Information progress between all project actors should be timely and properly organized, and the one responsible for the decision should be known by all the actors (Ruuska 2007, p. 83). This way the teams' actors exchange knowledge and opinions to enhance the output of the whole team (Katzenbach & Smith 1993). Nowadays, the teams in a construction project must face continually new challenges when projects are ever more complex and more demanding (Chan et al. 2004, p. 154).

A working communication system is a basic prerequisite for an effective and goal-oriented work community. Work community means a group of individuals who thrive for common goals and objectives systematically by using the resources they have available. A work communication system means those messages that make achieving those goals possible. Work community must have access to a communication system that consists of the rules of communication, used channels and predefined arrangements. (Ruuska 2007, p. 84)

Construction projects are technically complex, schedule dependent and multidisciplinary natured, requiring management and execution by a professional project group which is composed from different stakeholders' organizations (Thomas et al. 1998, p. 58). Hassan (1995, p. 22) says that construction project demands good team spirit between different stakeholders, because the successful completion of a project needs a team work between all the stakeholders, and it should be remembered that the failure of one stakeholder means the failure of all the stakeholders. Project organization must check if the project environment is advocating common interests (Zall et al. 1994, p. 573).

Larson (1995) states that the success of the project is surer if the owner and contractor are able to function as a team and to pursue common goals. The owner and the contractor should be able to define common processes for problem solving, and in addition, similar interaction should be created with all the stakeholders. Although Hassan (1995, p. 24) claims that direct communication between sub-contractors and owner should not take place, but the site organization should act as a filter, or a gatekeeper, in all communication between these two. Belassi and Tukel (1996, p. 145) also underline the necessity of communication platforms between project managers, project managers' organization and the owner of the project, so that the owner has a possibility to accept projects outcome. Comprehensive communication is a key factor in leading people and uniting them, as well as in decision-making, when the goal is to create a successful project. It is necessary to create an efficient information system in a construction project that allows all the stakeholders to share information and get access to ideas. A common vision of the project is impossible if stakeholders have poor communication with each other. The more people get information and more aware they are of what is happening in the project, the more they are involved which in turn leads to better motivation. (Nguyen et al. 2004, p. 410-411).

A good example of problems in communication is the interaction between design and building organizations. The communication methods used today do not encourage to develop these interactions. As a result, the connection between design information and building information is not unambiguously determined, and the connection between the designing of a certain part and scheduling the construction of that part is mainly in the heads of the involved professionals. Communication between design management and construction management is only partially supported because mainly the end results are communicated. Interaction between design and construction slows down when the thoughts behind design and construction are not communicated. Many construction companies are developing information exchange processes, but everyday information exchange is clouded by the isolation of information. Projects' information is often located in

miscellaneous and separate locations, such as in the minds of individuals, literature, building regulations, computer programs, drawings and project banks. Combining information from all these locations is challenging. (Luiten & Tolman 1997, p. 113)

Instances where turnover of workers inside a construction projects network is great, it is vital to get individuals to link with each other more and faster so that they can be quickly productive parts in the organization (Jaselskis & Ashley 1991; Cross et al. 2002). Cross et al. (2002, p. 38) have shown that when one individual leaves the project network it is not only the individuals' knowledge that is left from the network, but it can affect essentially how the network functions. Figure 7 shows how a few individuals work as bridges and links inside one big company. Staff turnover effects on projects' probability to achieve budget and schedule, which is illustrated in Figure 8 (Jaselskis & Ashley 1991, p. 321).

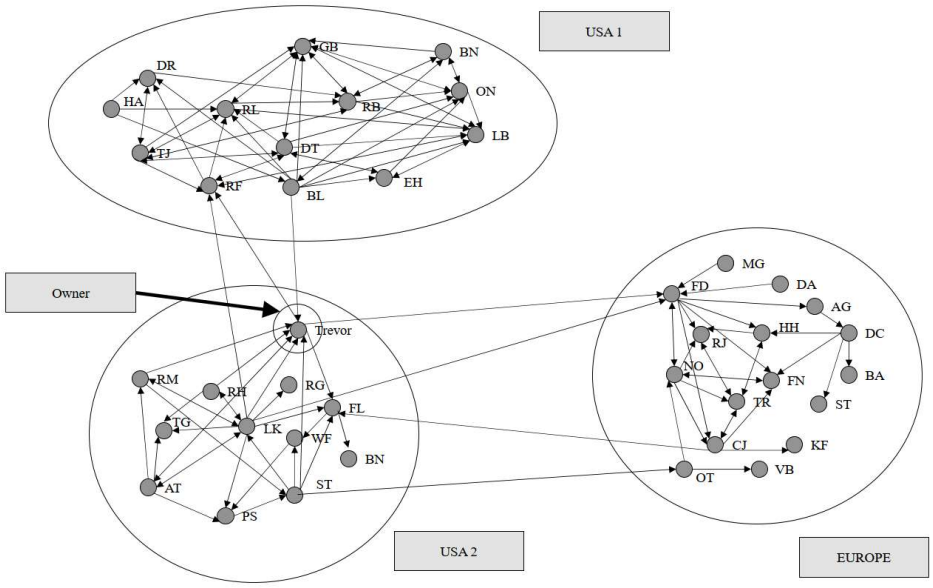

Figure 7. *Relevance of intermediaries in a network. Modified from source: (Cross et al. 2002, s. 38)*

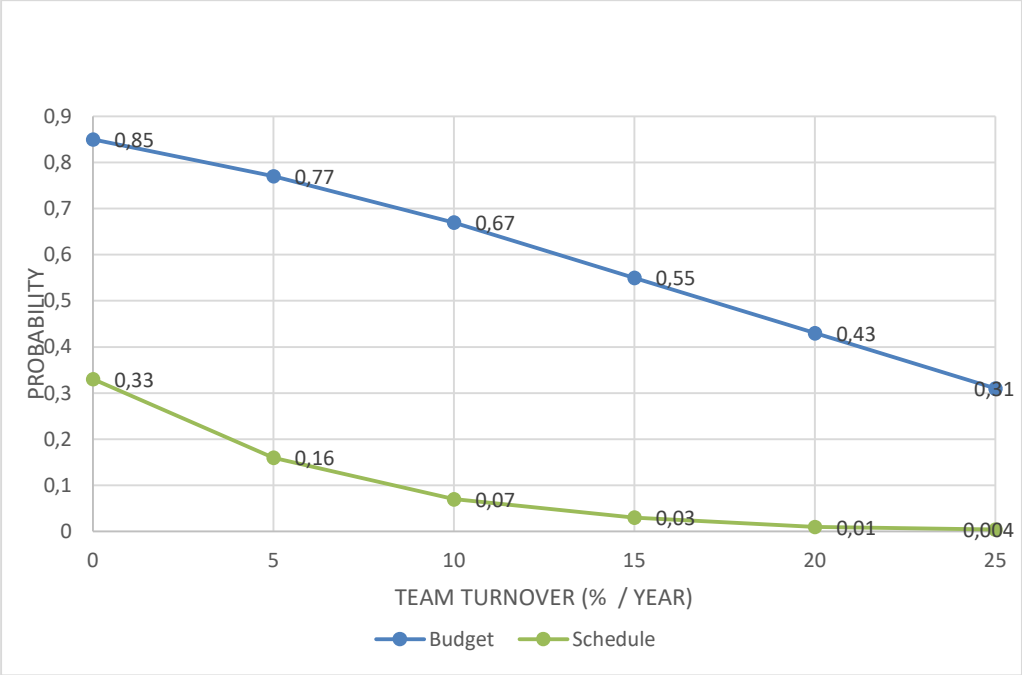

Figure 8. *Effects of personnel turnover on projects' budget and schedule. Modified from source: (Jaselskis & Ashley 1991, p. 332)*

Although research has underlined the importance of effective communication for the success of a project, there are very few suitable and reliable indicators to actually measure it. Thomas et al. (1998, p. 65) found a direct link between effective communication and the success of a project. Based on statistical analysis 41 percent of the variation in the perceptions of project success can be shown to be due to variation in communication

effectiveness. This direct link shows that increasing projects communication can further the performance of the project and influencing the variables they define could be a potential tool to help projects' success. Thomas et al. (1998, p. 58) have divided critical communication variables that can be used to improve communication of the project in six different categories. In order of priority, they are following:

1) Accuracy
2) Processes
3) Obstacles
4) Understanding
5) Timeliness
6) Completeness

Accuracy can be measured by the frequency of conflicting information, by lack of coordination or by other indicators of poor communication. A production plan or another similar document can help to define official processes, methods and scope of the project. Obstacles and filters are potentially the most difficult area of improvement, because they can be caused by personal problems that are impossible for project manager to solve. Other barriers can be reduced through education. Also lack of understanding can be difficult to verify or improve and besides, it may have existed a long time before the problems caused by it occur. A lack of timing is common in construction projects though many project managers are willing to focus on this problem and create processes to improve it. Completeness of information can be caused by problems in other categories. (Thomas et al. 1998, p. 64-65)

3.3 Social network analysis in construction

Social network analysis has not been used much to study construction. The author of this thesis did not find any studies that would have been done on social network analysis in the Finnish construction sector. However, Soda and Usai (1995) studied networks of contractors and noticed that the ones co-operating together have a higher rate of winning contracts. Loosemore (1996; 1998; 1999) has used social network analysis to study crisis situations and especially how the networks between different actors form up in these type of situations. Chinowsky et al. (2008) used social network analysis when studying the relevance of social networks in information exchange and developing high performance teams. Pryke (2012) has studied the differences in communication and information exchange between four different forms of procurement in the UK by using social network analysis. The aim of his study was to understand how SNA and the sociograms could be used to understand how the internal systems of construction projects work. Two

of the four studied sites were public construction projects and two were private sector construction projects. Making a perfect comparison between construction projects is challenging. Pryke (2012) says that a construction project is not repeatable. In an ideal setting the comparison would happen between two similar projects happening at the same time, with the same personnel, in the same environment, but with different forms of contact, this naturally is not feasible.

Pryke (2004) suggests that construction project can be thought as a network of companies that work together to achieve a common goal and aim for long-lasting collaborations. In a construction project, the greatest isolations do not happen inside companies but between them. That is why discussions about integration should concentrate on the integration between different interest groups (Winch 1989, p. 334). Pryke (2004, p. 787) adds that a construction project consists of a group of information exchange networks, that have been categorized by their project functions. An actor's centrality in these networks gives quantitative data and a graphical description how the project is led and how new innovative management can affect the network. Chinowsky et al. (2008, p. 806) state that networks can be found in every professional activity and all the networks perform, in essence, the same way as information, responsibilities and end results are defined between the members of the network. In construction projects it is typical that actors in the network lose cohesion because every interest group is driven by their own interest and not by the good of the whole network. In these types of networks, the density of the network and the distance between actors are the most critical when studying the weaknesses of that network. Chinowsky et al. (2008, p. 806) state that graph theory and SNA offer two following key advantages when studying construction industry:

- Established mathematical measurements that work as a base for quantitative analysis of network relationships and topology.
- Established viewing and modelling formats that allow representing interactions between the actors in the network

Approaching a project through social network analysis emphasizes the free flow of information between all the actors contributing to the project and concentrates on the dynamics of interactions. Usually, other methods present the construction project as a linear process that does not include much communication. Because of this, many diagrams are used to follow the progress of the project and instructions are the main form of communication used in the contracts. Using SNA is justified because when using SNA, it is possible to notice and compare changes in actors' roles and relationships by analyzing their centrality in the given network. (Pryke 2004; Pryke 2012).

Thomas et al. (1998, p. 65) suggest that construction organizations improve their communication through various programs and Cross et al. (2002, p. 39) think social network analysis has a possibility to make invisible information exchange networks and the forms of it visible beyond the traditional boundaries of the organization. By using the tools given by SNA it is possible to identify problems hindering the work of different groups inside the organization and to help making decisions that can modify the structure of the organization and increase productivity.

4. SUMMARY

This research on SNA was done based on literature survey. The goal was to study if the social network analysis offers a novel possibility to study different communication networks in a construction project and, if available, what type of construction projects have already been studied using SNA. A lot of research has been done on both social network analysis and the importance of communication in construction projects. Many of the studies underline the good communication between stakeholders and project groups as a key factor in a successful project, but only a few have studied how to measure it. Based on the literature, it is the possible to adopt social network analysis to study construction projects' communication networks and thus get quantitative data that can be evaluated using the tools SNA is offering.

No publications were found on applying social network analysis in Finland to study construction projects communication networks, and even around the world there has been only a handful of studies where social network analysis has been used to study construction projects. One possible future research subject could be the use of network analysis to study how the communication networks work in a construction project. Other possible research subject could be other methods to measure communications effectiveness in a construction project.

The goal of this study was to determine whether social network analysis can be used to study construction projects' communication networks. Literary review proved that construction projects can be considered as networks. These networks can be communication networks or networks changing different type of recourses. Tools that social network analysis offers to study networks were also studied based on literature. Social network analysis offers a wide range of tools for evaluating and actually measuring how networks are formed and how different actors communicate with each other, and the possibility to estimate the effectiveness of individual actors and the networks they influence. Because of the unique nature of construction projects social network analysis might not be that useful when comparing different projects' networks to each other. But for illustrating how different networks work inside one project and what roles different actors have in those networks, SNA can be a valuable tool.

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